Non-rigid Transformations for Musculoskeletal Model

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1 Introduction

The roadmap Vicenconti and Clapworthy (2011) states importance of registration of data sets for creation of the *Virtual Physiological Human*, a model of a human body. Registration is a process that finds correspondences between two data sets and allows the projection of parameters from one to the other. This allows the combination of many lifetime measurements of a single patient during his or her treatments of individual health issues into one large human body model with multiple detail scales and time axes. The roadmap also mentions usage of morphing technique for interpolation of new data from multiple input sources as we usually do not have complete data sources for every part of a single human body from naturally gathered test results. The morphing then allows to combine multiple datasets from population samples matched by previous registration to the same real world object resulting in a single new dataset not contained in the original input and sharing some degree of similarity with all of them.

Our work focuses on transformations tied with these operations and tries to find an automatic solution which does not need user set up parameters. The deformation filter for surface models of muscles in musculoskeletal model of human body developed in the previous work Kohout et al. (2012) was chosen as testing application. It has difficulties with damaged input meshes, especially those containing non-manifold edges and vertices. Therefore, the goal is an automatic detection and removal of such artifacts, and the combination of several such inputs into one finer mesh surface gained using a multi-morphing method.

2 Proposed Solution

The input of our application are surface triangular meshes, models of an identical muscle or bone. They can be non-manifold, have holes and have general rigid transformation in space. Although they represent the same real world object they come from various sources, e.g. different scanners, triangulation techniques, etc. and, therefore, they are not identical in number of vertices, size of triangles, topology, artifacts nor even shape. This all have to be dealt with and one fine surface mesh without non-manifolds or holes has to be produced as approximation of their shapes.

Two various solutions were proposed, but we will focus will on the better performing one only in this abstract. The Figure 1a shows main steps of the algorithm. First all input meshes artifacts are refined. This means that non-manifold edges and vertices are detected and removed. Also some potentially isolated graph components are cut off. Then all original and newly created holes are filled generating manifold genus 0 meshes. In the second phase, *Principal Component Analysis* (*PCA*) is used to find main axes of meshes and uses them to achieve rigid alignment. Then in the third step, non-rigid method based on iterative minimisation of distance between surface points of pairs of meshes is used to smoothly deform inputs and achieve very precise alignment. This allows the step 4 to choose a single input mesh as so called *su-*

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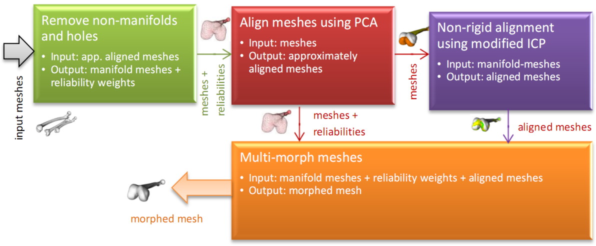
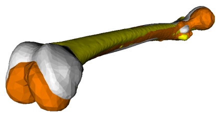
permesh and find barycentric coordinates of its vertices in the precisely aligned versions of the other meshes. These coordinates can then be used for original meshes stating interpolation points for final morphing. The supermesh vertices are then recalculated as average of all meshes and they form the final output of the method.



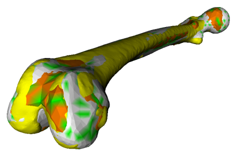
(a) Flow diagram

(b) Input meshes

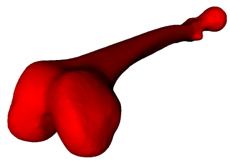
(c) After artifact removal



(d) After init. alignment



PCA **(e)** After non-rigid ICP



(f) Output of direct morphing

Figure 1: Flow diagram of method and outputs of individual main steps for three Femur bones.

3 Results

The figure 1 describes output of all steps on three models of a femur bone (Figure 1b). They are refined (Figure 1c), rigidly (Figure 1d) and non-rigidly (Figure 1e) aligned using registration and then combined using the morphing (Figure 1f). The result is a single final mesh with features of all inputs.

4 Conclusion

The method was tested on both original and artificially damaged input meshes. The resulting meshes do not have any non-manifold features and they well approximate the shape of original input meshes. It was also verified that this improves stability and precision of the formerly developed deformation filter Kohout et al. (2012). The method does not need any user specified parameters, e.g. distinctive feature points on surfaces defined on all inputs in some other methods. It is therefore outline of mechanism that should be developed for the announced *Virtual Physiological Human* Vicenconti and Clapworthy (2011).

References

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